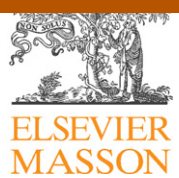
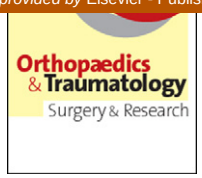
Orthopaedics & Traumatology: Surgery & Research (2010) **96**, 97—103



Available online at ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com



ORIGINAL ARTICLE

The Charnley stem: Clinical, radiological and survival data after 11—14 years

K. Bjørgul[a,*,d], W.M. Novicoff[a], S.T. Andersen[b], K. Brevig[c], F. Thu[d], M. Wiig[e], O. Åhlund[d]

[a] *Department of Orthopaedic Surgery, University of Virginia Health System, PO Box 800159, Charlottesville, VA 22908-0159, USA*
[b] *COXA Ortopedikonsult, Glenneveien 8, 1781 Halden, Norway*
[c] *Ostfold Hospital Trust, Sollihogda 21, 1783 Halden, Norway*
[d] *Orthopaedic Department, Ostfold Hospital Trust, 1603 Fredrikstad, Norway*
[e] *Fredrikshald Klinikk Mogens Wiig, Dyrendalsveien 13C, 1778 Halden, Norway*

Accepted: 10 November 2009

KEYWORDS
Hip arthroplasty;
Femoral component;
Cemented

Summary
Background: The Charnley stem provides good outcome for 10 years, but several studies find deteriorating results thereafter. However, study populations, techniques and data analysis vary widely. We have studied 240 Charnley stems in a homogeneous group of patients providing clinical, radiological and survival data after 11—14 years.
Hypothesis: The clinical and radiological outcome of the Charnley stem is not as good than previously thought.
Patients and methods: Five surgeons implanted 240 femoral stems in a community hospital in Norway using antibiotic impregnated cement and third generation cementing techniques. The Charnley stems were implanted with a Charnley cup in 120 cases and an uncemented hemispherical cup (Duraloc™) in 120 cases. The mean age of the patients was 65.5 years and the mean Body Mass Index (BMI) was 26.8. All patients received low molecular weight heparin and antibiotic prophylaxis. Patients were assessed after 10 years by means of Harris Hip Score (HHS) and radiographic evaluation. Implant survival studies were performed after 11—14 years.
Results: One hundred and fifty-eight patients were available for clinical and radiographic evaluation after 10 years. HHS improved from 48.4 (95% CI: 46.6—50,2) preoperatively to 87.9 (95% CI: 86.6—89.3) after 6 months and 87.6 (95% CI: 85.3—89.8) at 10 years. Thirty-one stems had been revised, the reasons for revision were loosening (21), infection (five), instability (four) and late perisprosthetic fracture (one). Forty-one stems had one or more signs of loosening. Stem survival was 83.6% using any revisions as end point, and mean estimated stem survival was 12.7 years (12.2—13.3 years).
Discussion: Other studies report survival at mid-term from 83—96%. Our results are in the low-end. Even though our rate of infection was high (2%), the main cause of the poor results

* Corresponding author. Tel.: +434 243 0067; fax: +434 243 0242.
E-mail address: krisbjorgul@gmail.com (K. Bjørgul).

1877-0568/$ - see front matter
doi:10.1016/j.otsr.2009.11.002

is aseptic loosening. We do not know the reason for this high-rate of loosening. As we believe that our technique is adequate and patient population average, we suspect that this rate of loosening is a characteristic of the implant. Results from this prospective cohort study add to the evidence that the Charnley stem should not be used hip arthroplasty unless patient life expectancy is less than 10 years.
Level of evidence: Level 2 prospective clinical study.

Introduction

Total hip arthroplasty (THA) is an effective treatment for end-stage degenerative disease of the hip joint, and the Charnley low friction arthroplasty has been regarded as a gold standard. Multiple reports document the outcome of the arthroplasty after up to 35 years, but patient populations, techniques and outcome measures vary widely. Generally the outcome of the Charnley arthroplasty has been successful for 10 years, but several studies have reported increasing rates of revision beyond 10 years [1—5]. Nevertheless, the Charnley stem continues to be highly regarded, and is still the stem to which others are compared in the Norwegian arthroplasty register [6]. Registry data provide valuable knowledge, but has been criticized for relying merely on survival data, disregarding clinical and radiographic outcomes.

Some long-term studies report results utilize older cementing techniques [7] or contain heterogeneous patient populations [1]. Also, outcomes data are reported in a variety of ways. A recent report on Charnley arthroplasties found an implant survival rate of 83% at 13 years but only a 76% clinical success rate [8].

We have investigated the outcome as well as survival data of 240 Charnley stems after 10 years implanted at a community hospital in Norway implanted with contemporary cementing techniques and report our results in terms of clinical success and radiographic findings at 10 years as well as implant survival after 11—14 years.

Patients and methods

Patients and surgical methods

Between April 1994 and June 1997, 215 patients treated at one clinic consented to take part in the study. Twenty-five patients consented for both of their hips, resulting in a total of 240 hips enrolled.

Patients were grouped according to the Charnley classification (Table 1) [9]. All surgeries were performed by five surgeons using a direct lateral approach [10] and third generation cementing techniques with vacuum mixing, retrograde filling of the canal, and pressurization prior to insertion of the femoral component [11]. Cement preloaded with gentamycin (Palacos™) and a Charnley stem (DePuy, Leeds, UK) with 22.225-mm head diameter was used in all cases, and a variety of stem shapes were available (Table 2). The acetabular component was a cemented Charnley Ultra High Molecular Weight Polyethylene (UHMWPE) cup (DePuy, Leeds, UK) in 120 cases and a uncemented porous coated Duraloc 1200™ cup (DePuy, Leeds, UK) in 120 cases. We used randomization by means of closed envelope for allocation of acetabular components.

We used dalteparin (Fragmin®), a low molecular weight heparin, 5000 IE subcutaneously for prophylaxis against thromboembolic events on the night before surgery, 4—8 h

Table 1 Charnley classification including modification of group B.

A	Single joint arthropathy and no significant medical comorbidity	112
B	One other joint in need of an arthroplasty, or an unsuccessful or failing arthroplasty in another joint	118[a]
B1	Contralateral hip in need of arthroplasty, but untreated	64
B2	Contralateral hip has been successfully treated with an arthroplasty	54
C	Multiple joints in need of arthroplasty, multiple failing arthoplasties or significant medical or psychological impairment	10

[a] B1 + B2.

Table 2 Diagnosis, age and type of implants used in the study.

Diagnosis	
Osteoarthritis	187
Congenital hip dysplasia	42
Post-traumatic arthritis	6
Rheumatoid arthritis	4
Avascular necrosis	1
Sex	
Male	64
Female	176
Types of implants	
Flanged 40	115
Roundback 40	30
Long neck	24
Extra heavy long neck	13
Roundback 45	24
Short neck	1
Flanged 45	24
Extra heavy flanged 45	9

Table 3 Harris Hip Score, scales and subscales indicating the points possible for each subscale.

Pain	44
Function	46
Gait (33)	
Limp (11)	
Support (11)	
Distance (11)	
ADL (13)	
Stairs (4)	
Socks (4)	
Sitting (4)	
Transportation (1)	
Range of motion	6
Absence of deformity	4
Total points	100

postoperatively and thereafter daily for the length of the stay, which mean was 8.5 days (2—13 days). Cefuroxim (Zinacef®) was given routinely in the study period for 1 day. Postoperatively we allowed patients restricted weight bearing on the day after surgery and all were encouraged to use two crutches for at least 6 weeks.

In this prospective randomized trial, not all variables of interest were recorded prospectively. For that reason, we undertook a chart review looking for the following parameters: length of stay, details on the use of antibiotics both as a primary prophylaxis and as secondary treatment for postoperative infections, detailed dosage of thromboprophylactic agents. Appearance of an antibiotic in the charts was interpreted as an infection. We were not able to find details on urinary analysis or other hard evidence regarding the etiology of an infection. However, the type of infection was inferred from the type of antibiotic employed.

Methods of assessment

Patients were seen by a physiotherapist at 6 months, 2 years, 5 years, and 10 years after surgery who obtained a Harris Hip Score (HHS) [12] at each visit (Table 3). For this study we computed mean scores with 95% confidence intervals. For the final follow-up we also computed pain scores and functional scores in brackets by 10. Radiographs were obtained at all visits and analyzed by a radiologist not directly involved in the study. Radiographic changes were described according to the femoral zones of Gruen et al. [13]. Changes have been included in the present analysis if recorded as larger than 2 mm, irrespective of length within the zone. In addition to the clinical scores (HHS), radiographic analysis and revision rates at 10 years, we calculated implant survival rates. This was done by performing a survival analysis in August 2008 (11—14 years postoperatively), using August 31st as a sensoring date.

Statistical methods

Two-sample *T*-tests were used for comparing continuous data, Chi^2 tests were used to compare proportional data. Survival data were analyzed using Kaplan-Meier plots and Cox regression analysis was used looking for possible predictors of failure. *P*-values lower than 0.05 and non-overlapping 95% confidence intervals were regarded as denoting statistically significant differences.

Results

Fifty-eight men and 157 women were enrolled in the study. Demographic information is shown in Tables 3 and 4. For the 10-year follow-up, we were able to assess 158 cases that had both radiographs and HHS. Twenty-six patients were deceased and 25 patients could not attend a clinical and radiographic examination due to advanced age and concomitant illnesses. None of these patients had been revised.

Harris Hip Score

HHS improved from a mean baseline value of 48.4 to 87.9 at the 6-month control (Table 5). There was also a significant improvement from 6 months to 2 years, and a drop from 5 to 10 years. After 10 years, HHS by 10-point brackets indicates that 20 of 158 cases scored lower than 70 points (13%). The lower values of total HHS is composed of a concomitant deterioration of function and increase in pain (Table 6).

Radiographic results

There were one or more signs of loosening in 41 of the 158 cases (26%) available for 10-year follow-up. There was no

Table 4 Age and Body Mass Index (BMI) at surgery.

	Mean	95% Confidence interval for mean	
		Lower bound	Upper bound
Age	65.5	64.6	66.5
BMI	26.8	26.2	27.3

Table 5 Harris Hip Score at baseline and each follow-up including 95% confidence intervals, minimum and maximum values.

	N	Mean	95% Confidence interval for mean		Minimum	Maximum
			Lower bound	Upper bound		
Baseline	240	48.4	46.6	50.2	6	94
Six months	237	87.9	86.6	89.3	41	100
Two years	225	91.3	89.9	92.7	45	100
Five years	191	91.0	89.4	92.7	38	100
Ten years	158	87.6	85.3	89.8	21	100

Table 6 Harris Hip Score (HHS) in brackets by 10 and corresponding pain and function score including 95% confidence intervals.

HHS	*N*	Pain score			Function score		
		Mean	95% Confidence interval for mean		Mean	95% Confidence interval for mean	
			Lower bound	Upper bound		Lower bound	Upper bound
90—100	91	43.7	43.5	43.9	44.1	43.5	44.6
80—89	38	42.0	40.7	43.3	33.6	32.2	35.0
70—79	9	40.0	34.8	45.2	27.3	22.7	31.9
60—69	11	36.9	31.5	42.4	20.0	13.6	26.4
<60	9	22.0	9.8	34.2	16.3	1.1	31.5
Total	158	41.4	40.3	42.5	37.8	36.2	39.3

association between radiographic signs of loosening and HHS (Table 7), as five of the 20 patients with HHS below 70 had one or more signs of loosening and 36 of 138 with HHS above 70 had signs of loosening. Conversely, of the 117 patients with no signs of loosening, 15 patients had a HHS below 70 (13%).

Revisions

At the time of the last follow-up, 31 hips had been revised (Table 8), 17 in the Charnley group and 14 in the Duraloc group ($P = 0.42$; Chi^2). Aseptic loosening was the most common reason for revision and this occurred in 21 cases followed by infection (five), instability (four) and one case of periprosthetic fracture.

The five infected hips were treated with two-stage revision after 5, 11, 14, 24 and 48 months, all five occurred in the Charnley group. There was a significant association between secondary use of antibiotics and later infection ($P = 0.001$; Chi^2). Only one of the 188 patients who did not have a postoperative urinary tract infection developed a hip infection, whereas four of the 41 patients with postoperative urinary tract infection later became infected. Relative risk for prosthetic infection is 18.3 when a postoperative infection occurred. The patients that became infected were significantly older (71.2 vs. 65.4 years; $P = 0.035$; *T*-test) than the patients that did not become infected.

With aseptic loosening as end-point, implant survival was 88.9% whereas survival with all causes for revision as end-point was 83.6%. The estimated mean survival of femur according to the Kaplan-Meier analysis was 12.7 years (95% confidence interval: 12.2—13.3). In the Cox regression analysis we did not find any variables that predicted stem survival.

Table 7 Number of patients with radiological signs of loosening by Harris Hip Score (HHS).

HHS at 10 years	Number of radiological signs of loosening				Total
	0	1	2	3	
90—100	70	7	11	3	91
80—89	26	5	5	2	38
70—79	6	0	2	1	9
60—69	9	0	1	1	11
<60	6	1	1	1	9
Total	117	13	20	8	158

Dislocation and other complications

Seventeen patients reported instability, five out of 120 in the Charnley group (3.3%) and 12 out of 120 (10.0%) in the Duraloc group ($P = 0.098$; Chi^2). There were 33 complications that were not treated surgically, 15 in the Charnley group and 18 in the Duraloc group ($P = 0.32$; Chi^2).

Table 8 Reasons for revision and mean time (range) to revision.

	Number of cases	Years to revision (range)
Aseptic loosening	21	5.7 (1—13)
Infection	5	1.7 (0—4)
Instability	4	2.8 (1—5)
Fracture	1	0.9

In the retrospective chart review, 52 cases (24 in the Charnley group and 28 in the Duraloc group) were identified in which a second course of antibiotics was given, of which 41 cases were given antibiotics indicating a urinary tract infection and 11 cases other antibiotics, indicating a range of infection types.

Discussion

Determining the long-term outcome after THA requires large studies, which are demanding and expensive. For that reason, many studies now originate from arthoplasty registries. Arthroplasty registries are powerful tools that provide insights in the performance of implants in specific regions. Originally designed to identify inferior products, most provide revision rates or survival rates as the only outcome measure. Survival data does not provide any information on the clinical status of the patient and every implant that is unrevised is considered a success. For that reason it is important to supplement reports from arthroplasties with reports which also provide a clinical and radiological outcomes. Moreover, registries depend on reliable reports on revision surgery. Revision surgery is often performed at a different hospital many years later, and failure to report the revision may falsely improve survival data. Also, it is well-known that the composition of the patient populations may vary with regards to gender, age and Body Mass Index (BMI) and preoperative functional level is important in predicting outcomes. Hence, clinical studies are a crucial supplement to arthroplasty registry studies.

Survival of the Charnley arthroplasty was reported to be between 90 and 95% in registries [14,15], and survival in clinical studies has been 85 to 96% [8,16—20] at mid-term (10—15 years). In our study, we found a survival of 84%, which was calculated as the number of surviving implants using the number of implants available at 10 years as the denominator. Using the original number of 240 cases the survival is 240—31/240 = 87%. We do not know the reason for our results in the lower range, but we believe that our technique and patient population is representative in terms of age, gender, BMI and activity level.

In our series, we used conventional cementing techniques aiming for a 2—3 mm cement mantle. However, the optimal cementing technique has not been determined. Good results have been obtained using an extremely thin cement mantle, as well (the French paradox) [21]. Utilizing the Charnley-Kerboull stem with only 25 reoperations in a series of 222 patients under the age of 50 years [22], and in another study the authors found a 15-year survival rate of 88.5% in patients treated for osteonecrosis [23]. In a comparative study the authors found that the polished or satin finish was better than the matte surface [24].

HHS below 70 has been designated as a bad clinical outcome. Forty-four points of the HHS is assigned to pain and the rest is derived from some sort of physical activity. It is well-known that physical activity and patient function deteriorate with time, and HHS is therefore heavily influenced by patient function. For that reason a low HHS may signify a low-level of activity more that unsuccessful arthroplasty beyond 5—7 years. However, in this study it is clear that the pain and activity scores deteriorate in a parallel fashion, which supports using HHS as a parameter for evaluate long-term outcome.

We found radiological signs compatible with loosening in 43 cases (32%). The mode of failure of the Charnley stem has been described [13] and is usually characterized by a radiolucent line in zone 1 followed by cement fracture around the tip of the stem and increasing radiolucencies in zones 3 to 5. Subsidence and displacement into a varus position ensues and there may be secondary cortical hypertrophy in zone 3. However, the speed with which this process progresses is variable and dependent on the total impact on the prosthesis. The total impact is determined by the weight of the patient and activity level. As the activity level of the patients declines with aging, a prosthesis with radiographic signs of loosening may remain stable and free of pain and not progress to revision. The patient should, however, be followed closely.

The relationship between radiographic findings and clinical outcome is complicated. In the study by Hulleberg et al. [8] 13 of 118 hips had a HHS <70, but among those only six were radiographically loose. Conversely, six of the hips with signs of loosening had a HHS >70, which was defined as clinically successful. In our study, 20 out of 158 hips scored <70 but only five of those had one or more signs of loosening, and none were deemed definitely loose. Beckenbaugh and Ilstrup found that only 8% of loose stems had required revision [25], and Ritter et al. found that 10 of 15 loose stems had been revised [20]. Hartofilakidis et al. revised 11 of 84 hips (13%) due to loosening of femur and acetabulum and another 11 of 52 (21%) femoral components displayed signs of loosening, but were unrevised [26]. The clinical outcome of patients with signs of loosening is often not described. In our study, we did not find any significant association between radiological signs of loosening and clinical outcome, but other authors have noted this association previously [25].

There are limitations to any long-term study of this nature. Because of death and deterioration in general health, only 158 patients were available for clinical and radiographic evaluation at the 10-year mark. While it is has been shown that the results in patients lost to follow-up are not as good as patients who stay in clinical studies [27], we were able to determine reason for loss to follow-up for almost all of our patients. The vast majority of those who declined a follow-up visit doing so because of advanced comorbid diseases, and not because of poor function of the hip. In addition, our overall follow-up rate was similar to other long-term studies of hip function, even though our patient population was significantly older [28—30].

The lack of precise recording of comorbidities is also a limiting factor. Indices of comorbidities have previously been shown to predict functional outcome as well as complications after THA [31—37]. Although the Charnley classification is recommended for identifying functional classes [38], it is not a validated comorbidity instrument, and might not be sensitive enough to record subtle nuances in patient health status. Recording level of activity is also important [39,40] as it is of primary interest to the patients for performing recreational activities [41] as well as for improving physical fitness, although increased level of activity correlates with wear and potential failure of an implant [42—44]. The HHS contains assessment of physical function,

but it does not quantify what the patient actually does, only what he or she is capable of doing. Dedicated scales have been developed for the sole purpose of estimating level of activity before and after THA, but these scales were not available for use in this study [44—47].

The issue of bilateral procedures is controversial since the presence of two procedures in one patient violates the assumption of independent observations that many statistical tests rely on [48—50]. However, other authors have discussed this and found that inclusion of bilateral procedures may not alter the results under certain circumstances [8,50]. According to our study protocol, the presence of an arthroplasty in the contralateral hip was not an exclusion criterion. Nor was there any criteria excluding patients with bad function of the contralateral hip that could be presumed to necessitate another hip replacement during the study period. It would also be vary hard to find patients with unilateral disease in sufficient numbers to do a long-term study as the other hip is known to need a replacement in at least 15% of the cases [50]. Hence, in our opinion, it was justified to include the patients who had two arthoplasties during the study and treat them as independent cases.

Conclusion

This study provides evidence in support of the poor outcome of the Charnley low friction arthroplasty after 10—14 years, documenting a revision rate of 13%, poor clinical outcome and radiographic signs of loosening in 26% of the cases. We do not recommend this implant for patients with a life expectancy in excess of 10 years, possible reserving the stem for hemiarthroplasties after hip fracture in the elderly population.

Conflict of interest statement

None.

References

[1] Wroblewski BM, Siney PD, Fleming PA. Charnley low-frictional torque arthroplasty in patients under the age of 51 years. Follow-up to 33 years. J Bone Joint Surg Br 2002;84:540—3.
[2] Hartofilakidis G. Survival of the Charnley low-friction arthroplasty. A 12—24-year follow-up of 276 cases. Acta Orthop Scand 1997;Suppl 275:27—9.
[3] Hozack WJ, Rothman RH. Long-term survival of the Charnley low-friction total hip arthroplasty. Semin Arthroplasty 1990;1:3—6.
[4] Callaghan JJ, Templeton JE, Liu SS, et al. Results of Charnley total hip arthroplasty at a minimum of thirty years. A concise follow-up of a previous report. J Bone Joint Surg Am 2004;86:690—5.
[5] Callaghan JJ, Liu SS, Firestone DE, et al. Total hip arthroplasty with cement and use of a collared matte-finish femoral component: nineteen to twenty-year follow-up. J Bone Joint Surg Am 2008;90:299—306.
[6] Furnes O, Havelin LI, Espehaug B, Steindal K, Søråas TE. Rapport 2008. Nasjonalt Kompetansesenter for Leddproteser; 2008, p. 50—50.
[7] Berry DJ, Harmsen WS, Cabanela ME, Morrey BF. Twenty-five-year survivorship of two thousand consecutive primary Charnley total hip replacements: factors affecting survivorship of acetabular and femoral components. J Bone Joint Surg Am 2002;84:171—7.
[8] Hulleberg G, Aamodt A, Espehaug B, Benum P. A clinical and radiographic 13-year follow-up study of 138 Charnley hip arthroplasties in patients 50—70 years old: comparison of university hospital data and registry data. Acta Orthop 2008;79:609—17.
[9] Charnley J, Halley DK. Rate of wear in total hip replacement. Clin Orthop 1975;112:170—9.
[10] Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg Br 1982;64:17—9.
[11] Rasquinha VJ, Dua V, Rodriguez JA, Ranawat CS. Fifteen-year survivorship of a collarless, cemented, normalized femoral stem in primary hybrid total hip arthroplasty with a modified third-generation cement technique. J Arthroplasty 2003;18:86—94.
[12] Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am 1969;51:737—55.
[13] Gruen TA, McNeice GMP, Amstutz HC. ''Modes of failure'' of cemented stem-type femoral components: A radiographic analysis of loosening. Clin Orthop 1979;141:17—27.
[14] Havelin LI, Engesaeter LB, Espehaug B, Furnes O, Lie SA, Vollset SE. The Norwegian Arthroplasty Register: 11 years and 73,000 arthroplasties. Acta Orthop Scand 2000;71:337—53.
[15] Allami MK, Fender D, Khaw FM, Sandher DR, Esler C, Harper WM, et al. Outcome of Charnley total hip replacement across a single health region in England. The results at ten years from a regional arthroplasty register. J Bone Joint Surg Br 2006;88:1293—8.
[16] Garellick G, Herberts P, Stromberg C, Malchau H. Long-term results of Charnley arthroplasty. A 12—16-year follow-up study. J Arthroplasty 1994;9:333—40.
[17] Kobayashi S, Takaoka K, Saito N, Hisa K. Factors affecting aseptic failure of fixation after primary Charnley total hip arthroplasty. Multivariate survival analysis. J Bone Joint Surg Am 1997;79:1618—27.
[18] Skeie S, Lende S, Sjoberg EJ, Vollset SE. Survival of the Charnley hip in coxarthrosis. A 10—15-year follow-up of 629 cases. Acta Orthop Scand 1991;62:98—101.
[19] Sochart DH, Hardinge K. Comparison of the Wrightington FC hip with the Charnley low-friction arthroplasty 10- to 15-year results and survival analysis. J Bone Joint Surg Br 1998;80:577—84.
[20] Ritter MA, Zhou H, Keating CM, Keating EM, Faris PM, Meding JB, et al. Radiological factors influencing femoral and acetabular failure in cemented Charnley total hip arthroplasties. J Bone Joint Surg Br 1999;81:982—6.
[21] Langlais F, Kerboull M, Sedel L, Ling RS. The ''French paradox''. J Bone Joint Surg Br 2003;85:17—20.
[22] Kerboull L, Hamadouche M, Courpied JP, Kerboull M. Long-term results of Charnley-Kerboull hip arthroplasty in patients younger than 50 years. Clin Orthop 2004;418:112—8.
[23] Nich C, Courpied JP, Kerboull M, Postel M, Hamadouche M. Charnley-Kerboull total hip arthroplasty for osteonecrosis of the femoral head a minimal 10-year follow-up study. J Arthroplasty 2006;21:533—40.
[24] Hamadouche M, Baque F, Lefevre N, Kerboull M. Minimum 10-year survival of Kerboull cemented stems according to surface finish. Clin Orthop 2008;466:33239.
[25] Beckenbaugh RD, Ilstrup DM. Total hip arthroplasty. J Bone Joint Surg Am 1978;60:306—13.
[26] Hartofilakidis G, Karachalios T, Zacharakis N. Charnley low friction arthroplasty in young patients with osteoarthritis. A 12- to 24-year clinical and radiographic followup study of 84 cases. Clin Orthop 1997;341:51—4.

[27] Murray DW, Britton AR, Bulstrode CJ. Loss to follow-up matters. J Bone Joint Surg Br 1997;79:254—7.
[28] Grobler GP, Learmonth ID, Bernstein BP, Dower BJ. Ten-year results of a press-fit, porous-coated acetabular component. J Bone Joint Surg Br 2005;87:786—9.
[29] Petersen MB, Poulsen IH, Thomsen J, Solgaard S. The hemispherical Harris-Galante acetabular cup, inserted without cement. The results of an eight to eleven-year follow-up of one hundred and sixty-eight hips. J Bone Joint Surg Am 1999;81:219—24.
[30] Clohisy JC, Harris WH. The Harris-Galante porous-coated acetabular component with screw fixation. An average ten-year follow-up study. J Bone Joint Surg Am 1999;81:66—73.
[31] Imamura K, Black N. Does comorbidity affect the outcome of surgery? Total hip replacement in the UK and Japan. Int J Qual Health Care 1998;10:113—23.
[32] Greenfield S, Apolone G, McNeil BJ, Cleary PD. The importance of co-existent disease in the occurrence of postoperative complications and one-year recovery in patients undergoing total hip replacement. Comorbidity and outcomes after hip replacement. Med Care 1993;31:141—54.
[33] Greenfield S. The state of outcome research: Are we on target? N Engl J Med 1987;320:1142—3.
[34] Keener JD, Callaghan JJ, Goetz DD, Pederson D, Sullivan P, Johnston RC. Long-term function after Charnley total hip arthroplasty. Clin Orthop 2003;417:148—56.
[35] Fortin PR, Clarke AE, Joseph L, et al. Outcomes of total hip and knee replacement: preoperative functional status predicts outcomes at six months after surgery. Arthritis Rheum 1999;42:1722—8.
[36] Groll DL, To T, Bombardier C, Wright JG. The development of a comorbidity index with physical function as the outcome. J Clin Epidemiol 2005;58:595—602.
[37] Lubbeke A, Katz JN, Perneger TV, Hoffmeyer P. Primary and revision hip arthroplasty: 5-year outcomes and influence of age and comorbidity. J Rheumatol 2007;34:394—400.
[38] Callaghan JJ, Dysart SH, Savory CF, Hopkinson WJ. Assessing the results of hip replacement. A comparison of five different rating systems. J Bone Joint Surg Br 1990;72:1008—9.
[39] Beaule PE, Dorey FJ, Hoke R, Leduff M, Amstutz HC. The value of patient activity level in the outcome of total hip arthroplasty. J Arthroplasty 2006;21:547—52.
[40] Dorey FJ, Amstutz HC. The need to account for patient activity when evaluating the results of total hip arthroplasty with survivorship analysis. J Bone Joint Surg Am 2002;84:709—10.
[41] Wright JG, Rudicel S, Feinstein AR. Ask patients what they want. Evaluation of individual complaints before total hip replacement. J Bone Joint Surg Br 1994;76:229—34.
[42] Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Meyer HE. The effect of middle-age body weight and physical activity on the risk of early revision hip arthroplasty: a cohort study of 1,535 individuals. Acta Orthop 2007;78:99—107.
[43] Lavernia CJ, Sierra RJ, Hungerford DS, Krackow K. Activity level and wear in total knee arthroplasty: a study of autopsy retrieved specimens. J Arthroplasty 2001;16:446—53.
[44] Saleh KJ, Mulhall KJ, Bershadsky B, et al. Development and validation of a lower-extremity activity scale. Use for patients treated with revision total knee arthroplasty. J Bone Joint Surg Am 2005;87:1985—94.
[45] Naal FD, Impellizzeri FM, Leunig M. Which is the best activity rating scale for patients undergoing total joint arthroplasty? Clin Orthop 2009;467:958—65.
[46] Silva M, McClung CD, la Rosa MA, Dorey FJ, Schmalzried TP. Activity sampling in the assessment of patients with total joint arthroplasty. J Arthroplasty 2005;20:487—91.
[47] Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. J Arthroplasty 1998;13:890—5.
[48] Ranstam J. Problems in orthopedic research: dependent observations. Acta Orthop Scand 2002;73:447—50.
[49] Bryant D, Havey TC, Roberts R, Guyatt G. How many patients? How many limbs? Analysis of patients or limbs in the orthopaedic literature: a systematic review. J Bone Joint Surg Am 2006;88:41—5.
[50] Lie SA, Engesaeter LB, Havelin LI, Gjessing HK, Vollset SE. Dependency issues in survival analyses of 55,782 primary hip replacements from 47,355 patients. Stat Med 2004;23:3227—40.